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METEOROLOGICAL

COMMUNICATION PACKAGE

Specific requirements to HRPT and LRPT

For Eumetsat Polar Mission

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This document provides a specification of the HRPT and LRPT services provided by the EUMETSAT Polar System (EPS).

The specification is based on the global HRPT/LRPT specification included in [AD01] and shall be read using [AD01] for general definitions such as the description of the different layers or the VCDU format ... This document is an **addendum to that** global specification.

The HRPT and LRPT links are characterised by the utilisation of packer telemetry and the encryption of individual virtual channels. The on-board encryption mechanism, based on the DES algorithm, is described in [AD02]. The encryption is addressed in this document. only to specify the content of the Insert zone in the VCDU data structure in the Data Link Layer.

This document covers the implementation of the data communication model on METOP1 and METOP2 spacecraft.

The structure of this document follows the communication model described in [AD01].

- Chapter 3 details the Application Layer implementation specific to the METOP mission
- Chapter 4 deals with the Network Layer implementation derails.
- chapter 5 deals with the Data Link Layer implementation details.
- Chapter 6 describes the LRPT Physical Layer.
- Chapter 7 describes the HRPT Physical Layer.

2 APPLICABLE DOCUMENTS

AD01 GFSC-S-480-77	Low Resolution and High Resolution Picture liansmission (LRPT/HRPT) Global Specification
AD02 EPS/MCP/SPE/92004	Encryption System for EUMETSAT Polar System (EPS)

3 APPLICATION LAYER

3.1 Application Data

3.1.1 Provided with LRPT

The application data provided by the Low Resolution Picture Transmission link are as follows:

- Reduced resolution imagery from the AVHRR instrument (sampling or compression scheme tbd).
- Infrared and microwave sounding data from the Meteorological Payload; AMSU-A. MHS, HIRS.
- DCS data.
- SEM data (optional).
- Housekeeping data.

The structure of the encryption key messages is specified in [AD02].

3.1.2 Provided with HRPT

The application data provided by the High Resolution Picture Transmission link are as follows:

- Full resolution AVHRR imagery .
- Infrared and microwave sounding data from the Meteorological Payload: AMSU-A. MHS. HIRS and IASI.
- SEM data (optional).
- DCS data.
- Climate monitoring data provided by ASCAT, MIMR, OMI (Ozone Monitoring), ScaRaB (optional).
- Housekeeping data.

The structure of the encryption key messages is specified in [AD02].

3.1.3 Implementation

The NOAA procured instruments (AVHRR. AMSU-A. HIRS. SEM, DCS) will generate raw data which will be formatted by the spacecraft NOAA Interface Unit (NIU). This NIU will also provide data compression of the AVHRR data for transmission on the LRPT link.

The NIU will be responsible for all commands and synchronisation signals. It will also time tag all raw data provided by the NOAA instruments.

The other instruments shall be responsible for the generation of their source packets.

3.2 Time Synchronization

Each instrument shall receive a clock signal and a time code information from the Platform.

The sounding instruments shall receive a **synchronization** pulse, with a duty cycle of 8 seconds.

The timing information shall be used by the instruments to maintain an accurate clock for time code generation. This data shall be made available to the network layer for inclusion in the source packets as necessary.

The synchronization pulse shall also be used as baseline for cyclic packet acquisition within the data link layer.

The time information is derived from the spacecraft clock The relation between this clock and UTC is determined by the Polar Satellite Control Centre. The time difference betwe these clocks shall be broadcast as part of the housekeeping messages, transmitted with a average duty cycle of 1 second.

Note: for the NOAA instruments, the timing and packetisation will be done by the NOAA Interface Unit (NIU).

3.3 Packet structure

TM source packets format is as follows:

Packet Primary Header (48 bits)			Packet Data Field (variable)		
Packet id 16	Packet sequence control 16	packet length 16	Data field header (UTC) 48	Source data variable	Error control field (optional) 16

Packet id:

- Version **number**	**000** (Version number 1)
- Type	0 (TM)
- Data Field Header Flag	I = presence of a **header.**
- Application Process id	see chapter 3.4.

Packet sequence control

- Sequence Flag	tbd.

- Packet name/sequence count : tbd

Packet length variable (see 3.4).

It is recommended to limit the size to 10000 octets for operational and coverage duration reasons. Segmentation should be used.

Packet secondary header : contains Unsegmented Time Code for **time** tagging.

Error control field **contains** Cyclic Redundancy Checksum (CRC) computed over the primary header and the source data field.

3.4 Application Process Identifiers

The following table provides an overview of the METOP application data; the overall size of one source packet (CP_SDU) is specified; the number of source packets forming one data ser is given; the data rate is implicitly given by the number of data set every 64 seconds; the associated APid is then given- The source packets belonging to one data set are logically connected with help of the sequence flags.

A data set is a self standing, measurement data acquired in a measurement cycle: on MIIS. it represents data acquired during one scan; on AVHRR, it represent the data related to one spectral channel in a scan; as housekeeping telemetry is acquired every second, 64 data sets are acquired in 64 seconds. ... Due to packet size limitation, there can be more than one packets in a data set.

All data sets except APID 0 (administrative message) and APID 1984 (encryption key' messages) are repeated one or more times every eight seconds. APID 0 data appears at a reduced repetition rate which is once per 64 seconds. APID 1934 data is inserted whenever possible, i.e. decoupled from the 8 seconds period.

Application	packetised data rate (kbps)	Packet size (octet)	Number of packets per data set	Number of data set / 64 s.	APid
Housekeeping data: administrative messages (0)	0.519	1038	1..8	1	0
Commanded memory dumps tbc	*tbd*	*tbd*	*1..tbd*	*Variable: one of the APid 1, 2, 3 used at a time*	*1*
Non-nominal realtime telemetry tbc	*tbd*	*tbd*	*1..tbd*		2
Extended history data tbc	*tbd*	*tbd*	*1..tbd*		*3*
Nominal realtime telemetry tbc	*tbd*	*tbd*	*1*	*64*	*4*
Orbit and attitude data tbc	*tbd*	*tbd*	1	*64*	*5*
Selected history data (tbc by METOP ESA team)	*tbd*	*tbd*	*1*	*8*	*6*
MHS	*3.840*	1280	1	24	34
DCS-2	2.574	2574	I	a	35
SEM (option)	.174	174	1	[illegible]	37
HIRS/2	2.894	2894	1	[illegible]	3
AMSU-A1 (5)	2.108	1054	1	16	39
AMSU-A2	1.1480	574	1	16	40
AVHRR/3 low resolution: 3 (tbc) of 5 channels to be transmitted simultaneously (one APid per spectral range) (1)	tbd <36	tbd	1 tbc	tbd	64.70
AVHRR/3 TELEMETRY, 3 (tbc) of 5 channels (one APid per spectral range) (2)	0.01s	20	1	6	71.75
AVHRR/3 high resolution (one APid for all channels) (3)	621.54	12928	3	128	103
IASI (5 source APid) (4)	1500	tbd	tbd	tbd	128..132
ASCATT	45	tbd	tbd	tbd	tbd
MIMR	100	tbd	tbd	tbd	tbd
Scarab (optional)	3	tbd	tbd	tbd	tbd
OMI	50	tbd	tbd	tbd	tbd
Encryption key messages	variable	a82	1	variable	1984

(0) : numbe: of packets may vary depending on operational requirements (4 packers per data set have been assumed)

(1) : each data set contains reduced (or compressed) data of **one AVHRR channel.**

(2) : each data set contains telemetry data from one channel.

(3) : each data set contains the instrument data from the equivalent of one major frame (tbc). The A VHRR source &a contains the TM data (10x10 bit), buck scan data (30x10 bit), Space &a (50x10 bit), AVHRR vi&o &a (102,400 bit). 6 frames per

second .

(4) : IASI APid and packers size will be provided at a later stage.

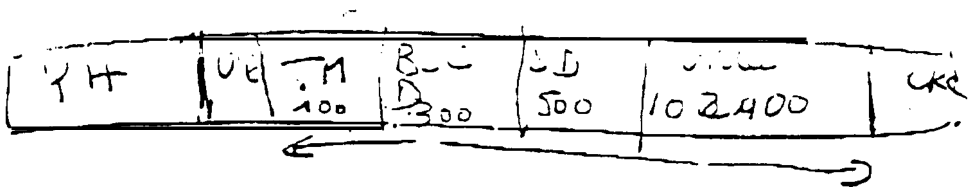
(5) : 2 packers per scan line (8s) for AMSU A1containing the Digital A data output (13 channels x 10x 4x 16 bit words); 2 packets per scan line (8s) for AMSU A2 containing the Digital A data output (7 channels x 10x 4x 16 bit words).

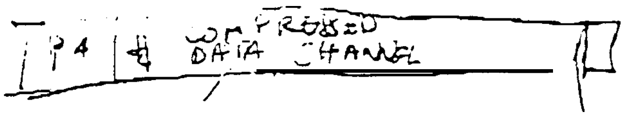
Note: the same instruments are supposed to fly on METOP 1 and METOP 2. SEM and Scarab are considered as options. Housekeeping data are provided by the Platform to the FMU.

5.5 LRPT AVHRR Source Packet

To be filled after a decision on adequate compression/ sampling scheme.

5.6 HRPT AVHRR S.P.





4 NETWORK LAYER

The Network layer shall generate correct VCDU id upon forwarding CP-PDUs to the multiplexing service.

4.1 Usage of VCDU-ID

The VCDU-ID is a data structure of 14 bits length, consisting of a spacecraft identifier (8 bits) and a virtual channel identifier (6 bits).

Spacecraft identifiers shall be assigned as follows:

Spacecraft	Spacecraft Identifier
METOP1	[tbd]
METOP2	[tbd]

The virtual channel identifiers are given by the subsequent table. Note that, for encryption purpose, the virtual channel (63), used by the data link layer for addressing fill VCDUs will be replaced by VC (62).

For the LRPT:

APID	Virtual Channel Identifier
0...31	0
34	12 (tbc)
35...63	3
64...95	5
1984	62

For **the** HRPT:

APID	Virtual Channel Identifier
0...31	0
34	12
35...63	3
96...127	7
128...159	10
tbd	15
tbd	17
tbd	18
tbd	22
1984	62

5 DATA LINK LAYER

5.1 Algorithm When to Insert Fill Packets

No fill packets shall be used with LRPT or HRPT. The mission itself ensures that any incomplete M_PDU for one VC can be completed within eight seconds.

5.2 Usage of VCDU Trailer

The optional VCDU trailer field is implemented on virtual **channel 0** ***only (tbc). The trailer field is filled with all zeros.***

On all other virtual channels there is no VCDU trailer.

5.3 Usage of VCDU Insert Zone

The insert zone is used for encryption control.

The structure of the IN_SDU used wish LRPT or HRPT is as follows:

Encryption flag	Consists of one octet, determining whether this VC is encrypted or not: all zeros — encryption off all ones — encryption on — KG-46
Key number	Consists of one octet, determining which message key is used to encrypt this VC. The binary value of this field equals the message key number (0. ..255). This field has no meaning if encryption is off and shall he set to zero then.

5.4 Algorithm on How to Commutate CVCDUs

Commutation of CVCDUs shall be performed on basis of a strong priority system: virtual channel 0 has the highest priority, virtual channel 62 has the lowest priority. Upon generation of each CADU the oldest CVCDU is taken from the highest priority (i.e. lowest VC number) virtual channel queue not being empty.

HRPT is constituted of 2 physical channels and the mapping of Virtual Channels to Physical Channels is done as below:

Virtual channels 0,3,7,9, 12, 15, 17, 18, 22 and 62 are mapped to physical channel I.
Virtual channel 10 and 62 are mapped to physical channel Q.

6 LRPT PHYSICAL LAYER

6.1 Radiation field

The LRPT link shall serve ground station equipments of two different types:

- Steerable antennas with a minimum elevation angle of 5 .
  Omnidirectional antennas with a minimum elevation angle of 13°

Antenna type	System G/T	min. S/C Elevation
steerable YAGI antenna	-22.4 dB/K	5°
omni-directional antenna	-30.4 dB/K	13°

The minimum power flux density on ground shall be -134 dBW/m^2 for an elevation angle of 5°.
the minimum — -126 dBW/m^2 — 13

- The radiation field shall be right hand circular polarized (RCP) with a maximum axial ratio of 4.5 dB. G/S

The ~~space link~~ shall be designed in such way that the resulting bit error rate after applying Reed-Solomon FEC does not exceed 10^{-6} under worst case consideration for 99.8 % of the coverage time with a minimum link margin of 3 dB. A FEC gain shall be assumed

For the purpose of establishing link budgets, the following parameters shall be taken into account:

Altitude: 824 km.

- Atmospheric i-rain losses: 0.1 dB.
- Polarisation mismatch losses + Antenna mispointing losses: 1.5 dB (tbc)
- Demodulator losses: 2 dB
- the FEC gain shall be assumed as 2 dB only.

6.2 Carrier

Parameter	Value	Unit
Nominal carrier frequency	137.1	MHz
Backup carrier frequency	137.9	MHz
Carrier uncertainty over lifetime	$\pm 2 \cdot 10^{-5}$	-
Spurious AM (*)	< -60	dBc/100Hz
Phase noise	< -60	dBc/100Hz

(*) : a higher filtering may be required on the 3rd harmonics to satisfy EMC with S&R.

6.3 Modulation

The service data unit (i.e. the NRZ-L data stream) is directly used to modulate the phase of the carrier. The phase of the carrier is advance during a logical "1" bitcell, and delayed during a logical "0" bitcell. There is no premodulation filtering on the baseband data.

The modulation parameters are listed in the following table:

Parameter	Value	Unit
Bit rate	72000	bps
Data clock uncertainty	$\pm 5 \cdot 10^{-5}$	-
Encoding scheme	NRZ-L	
Maximum data asymmetry for Alternating pattern	5% (TBC)	
Modulation scheme	BPSK	
Modulation index	1.57	rad
Phase state accuracy	tbd	
Maximum amplitude imbalance between any two phase states	0.4	dB

6.4 RF Filtering

Onboard the spacecraft, the RF signal (after modulation) is passed through a filter denoted as TX filter. The frequency response of the reception equipment up to (but not including) the demodulator is described as the so-called RX filter.

Both filters are optimized for minimum technological losses, i.e. smallest bit error rate for a given signal to noise ratio. Additionally, the TX filter has to ensure that 99 % of the signal energy is inside a baud of 150 kHz centred around the carrier.

For best performance both TX and RX filters shall be implemented as digital filters.

The TX filter is a concatenation of a whitening filter, followed by a roll-off filter. The roll-off factor (α) is 65 % while the repartition (γ) reach its optimum at 50%.

The optimum RX filter is a roll-off filter with a roll-off factor (a) of 65 % and a repartition (γ) of 50%.

7 HRPT PHYSICAL LAYER

7.1 Radiative field

The space link shall be defined in such way that the resulting bit error rate after applying Reed-Solomon FEC does not exceed 10^{-6} under worst case considerations with a 99.8% availability with a minimum link margin of 3 dB.

The receiving equipment shall perform a figure of merit nor lower than 6.5 dB/K for ground station elevation angles between 5° and 90°.

The HRPT Power Flux Density shall not exceed -154 dBW/m²/in 4 kHz at low elevation angles ($\delta < 5°$) and -154 + 0.5 (δ-5) dBW/m²/4 kHz for $25 > \delta > 5°$ as specified by International Radio Regulations.

The HRPT Power Flux Density shall not exceed -133 dBW/m²/in 1.5 MHz as specified by International Radio Regulations.

The minimum HRPT Power Flux Density shall be -131 dBW/m² in each channel bandwidth.

The radiation field shall be right hand circular polarized with a maximum axial ratio of 4.5 dB.

For the purpose of establishing link budgets, the following parameters shall be taken into account:

- Altitude: 824 km.
- Atmospheric + rain losses: 0.5 dB.
- Polarisation mismatch losses + Antenna mispointing losses: 1.5 dB (tbc).
- Demodulator losses: 2 dB.
- the FEC gain shall be taken as 4 dB.

7.2 Carrier

Parameter	Value	Unit
Nominal carrier frequency	1707	MHz
Backup carrier frequency	1701	MHz
Carrier uncertainty over lifetime	$\pm 2 \cdot 10^{-5}$	
Spurious AM	< -60	dBc/100Hz
...ase noise	C-60	dBc/100Hz

7.3 Modulation

Two service data units, each of them being an NRZ-L data stream, will be used to modulate the carrier. The modulation scheme is UQPSK, which is in fact the addition of two BPSK signals.

Each service data unit (i.e. an NRZ-L data stream) is directly used to modulate the phase of the carrier. The phase of the carrier is advance during a logical "1" bitcell, and delayed during a logical "0" bitcell. There is no premodulation filtering on the baseband data.

The bit rates of both channels are phase locked; three bit cells on the I channel and four bit cells on the Q channel are added together without any timeshift in-between.

The modulation parameters are listed in the following table:

Parameter	Value	Unit
Bit rate, I channel	1500000	bps
Bit rate, Q channel	2000000	bps
Data clock uncertainty	$\pm 5 \cdot 10^{-5}$	-
Encoding scheme	NRZ-L	-
Maximum data asymmetry for alternating pattern	5% (TBC)	-
Overall modulation scheme	UQPSK	-
Modulation index for each of the channels	1.57	rad
Phase state accuracy	tbd	
Maximum amplitude imbalance between any two phase states	0.4	dB
Attenuation I channel (P/P_I)	3.68	dB
Attenuation Q channel (P/P_Q)	2.43	dB

7.4 RF Filtering

Onboard the spacecraft, the RF signal of the I and the Q channel (after modulation) is passed separately through filters denoted as TX filters. The frequency response of the reception equipment up to (but not including) the demodulator, separated for I and Q channel, is described as the so-called RX filters.

Both filters are optimized for minimum technological losses, i.e. smallest bit error rate for a given signal to noise ratio.

For best performance both TX and RX filters shall be implemented as digital filters.

Each of the two TX filters is a concatenation of a whitening filter, followed by a roll-off filter. The roll-off factor (a) is 80% while the repartition (y) reaches its optimum ax 50%.

The optimum RX filter is a roll-off filter with a roll-off factor (α) of 80% and a repartition (γ) of 50%.

Figure 7-l visualizes the transfer functions of both filters.

Appendix A. List of Acronyms

AM	Amplitude modulation
BPSK	Binary phase shift keying
BER	Bit error rate
CCSDS	Consultative Committee for Space Data Systems
CVCDU	Coded virtual channel data unit
E_b/N_0	Bit energy ./. noise energy
EIRP	Equivalent isotropic radiance power
FEC	Forward error correction
G/S	Ground station
G/T	Figure of merit (antenna gain ./. system noise temperature)
MCP	Meteorological communication package
MCU	Meteorological package control unit
NRZ-L	Nonreturn-to-zero-Level
RF	Radio frequency
RHC	Right hand circular
s/c	Spacecraft
TBC	To be confirmed
tbd	To be defined
UQPSK	unbalance quadrature phase shift keying
UTC	Coordinated universal time
VC	Virtual channel
VCDU	Virtual channel data unit
VCDU-ID	Virtual channel data unit identifier